Appendix E.

Conversion Factors for Common Air Pollution Measurements and Other Useful Information for HTRW Sites

E-1. Introduction

The USACE project managers (PMs) and technical managers (TMs) are confronted with a multitude of confusing and conflicting emission units. A review of the literature demonstrates that confusion associated with reporting units. Many of the emission concentration units used by regulatory agencies are carry-overs from other environmental disciplines, such as water pollution studies, stack test emission monitoring studies, and industrial hygiene studies. While their methods of expressions are correct, their applications to air HTRW FFMS studies are often misleading.

The recommended units for reporting emissions associated with HTRW FFMS should be the metric system in whole numbers. If possible, the reported units should be the same as those that are actually being measured. For example, weight should be recorded in grams; volume of air should be recorded in cubic meters. When the analytical system is calibrated in one unit, the emissions should also be reported in the units of the calibration standard. For example, if a gas chromatograph is calibrated with a 1 ppm standard of toluene in air, then the emissions monitored by that system should also be reported in ppm. Finally, if the emission standard is defined in a specific unit, the monitoring system should be selected to monitor in that unit.

Consequently, the preferred reporting units for the following types of emissions should be:

- Nonmethane organic and volatile organic compound emissions . . . . . ppm, ppb
- Semi-volatile organic compound emissions . . . . . $\mu g/m^3$, ng/m^3
- Particulate matter (TSP/PM-10) emissions . . . . . $\mu g/m^3$
- Metal compound emissions . . . . . ng/m^3

E-2. Example Conversion from ppm to µg/m^3

Often, the environmental engineer, the PM or the TM must be able to convert from ppm to $\mu g/m^3$. Following is an example of how one would perform that conversion using SO_2 as the monitored constituent.

a. ***Discussion.***

The expression parts per million is without dimensions, i.e., no units of weight or volume are specifically designed. Using the format of other units, the expression may be written:

$$\frac{\text{parts}}{\text{million parts}}$$

"Parts" are not defined. If cubic centimeters replace parts, we obtain:

$$\frac{\text{cubic centimeters}}{\text{million cubic centimeters}}$$

Similarly, we might write pounds per million pounds, tons per million tons, or liters per million liters. In each expression, identical units of weight or volume appear in both the numerator and denominator and may be canceled out, leaving a dimensionless term.

An analog of parts per million is the more familiar term "percent." Percent can be written:

$$\frac{\text{parts}}{\text{hundred parts}}$$

To convert from part per million by volume, ppm_v ($\mu L/L$), to $\mu g/m^3$ at EPA's standard temperature (25°C) and standard pressure (760 mmHg), STP, it is necessary to know the molar volume at the given temperature and pressure and the molecular weight of the pollutant.

At 25°C and 760 mm Hg, one mole of any gas occupies 24.46 liters.

Convert the following:

2.5 ppm by volume of SO_2 was reported as the atmospheric concentration.

1. What is this concentration in micrograms (μg) per cubic meter (m^3) at 25°C and 760 mm Hg?

2. What is the concentration in $\mu g/m^3$ at 37°C and 752 mm Hg?

b. *Solution.*

Let parts per million equal $\mu L/L$ then 2.5 ppm = 2.5 $\mu L/L$. The molar volume at 25°C and 760 mm Hg is 24.46 L and the molecular weight of SO_2 is 64.1 g/mole.

1. 25°C and 760 mm Hg

$$\frac{2.5\ \mu L}{L} \times \frac{1\ \mu mole*}{24.46\ \mu L} \times \frac{64.1\ \mu g}{\mu mole} \times \frac{1{,}000\ L}{m^3} = \frac{6.6 \times 10^3\ \mu g}{m^3} \text{ at STP}$$

2. 37°C and 752 mm Hg

$$24.46\ \mu L \left(\frac{310°K}{298°K}\right)\left(\frac{760\ mm\ Hg}{752\ mm\ Hg}\right) = 25.72\ \mu L$$

$$\frac{2.5\ \mu L}{L} \times \frac{1\ \mu mole*}{25.72\ \mu L} \times \frac{64.1\ \mu g}{\mu mole} \times \frac{1{,}000\ L}{m^3} = \frac{6.2 \times 10^3\ \mu g}{m^3} \text{ at } 37°C,\ 752\ mmHg$$

*Since, at STP, 1 mole of a gas occupies 24.46 liters, 1 μmole = 24.46 μL

This sample problem also points out the need for reporting temperature and pressure when the results are presented on a weight to volume basis.

E-3. Conversion Tables for Common Air Pollution Measurements

To assist the environmental engineer, the PM, and the TM in converting from one set of units to another, the following conversion factors for common air pollution measurements and other useful information are provided. The conversion tables (Tables E-1 through E-5) provide factors for:

- Atmospheric gases.
- Atmospheric pressure.
- Gas velocity.
- Concentration.
- Atmospheric particulate matter.

Following is a list of conversions from ppm to $\mu g/m^3$ (at 25°C and 760 mmHg) for several common air pollutants:

ppm SO_2 x 2620 = $\mu g/m^3$ SO_2 (Sulfur dioxide)

ppm CO x 1150 = $\mu g/m^3$ CO (Carbon monoxide)
ppm CO_x x 1.15 = mg/m^3 CO (Carbon monoxide)
ppm CO_2 x 1800 = $\mu g/m^3$ CO_2 (Carbon dioxide)
ppm CO_2 x 1.8 = mg/m^3 CO_2 (Carbon dioxide)
ppm NO x 1230 = $\mu g/m^3$ NO (Nitrogen oxide)
ppm NO_2 x 1880 = $\mu g/m^3$ NO_2 (Nitrogen dioxide)
ppm O_3 x 1960 = $\mu g/m^3$ O_3 (Ozone)
ppm CH_4 x 655 = $\mu g/m^3$ CH_4 (Methane)
ppm CH_4 x 655 = mg/m^3 CH_4 (Methane)
ppm CH_3SH x 2000 = $\mu g/m^3$ CH_3SH (Methyl mercaptan)
ppm C_3H_8 x 1800 = $\mu g/m^3$ C_3H_8 (Propane)
ppm C_3H_8 x 1.8 = mg/m^3 C_3H_8 (Propane)
ppm F- x 790 = $\mu g/m^3$ F- (Fluoride)
ppm H_2S x 1400 = $\mu g/m^3$ H_2S (Hydrogen Sulfide)
ppm NH_3 x 696 = $\mu g/m^3$ NH_3 (Ammonia)
ppm HCHO x 1230 = $\mu g/m^3$ HCHO (Formaldehyde)

Table E-1
Atmospheric Gases

TO CONVERT FROM	TO	MULTIPLY BY
Milligrams/cu m	Micrograms/cu m	1000.0
	Micrograms/liter	1.0
	Ppm by volume (20°C)	$\frac{24.04}{M}$
	Ppm by weight	0.8347
	Pounds/cu ft	62.43×10^{-9}
Micrograms/cu m	Milligrams/cu m	0.001
	Micrograms/liter	0.001
	Ppm by volume (20°C)	$\frac{0.02404}{M}$
	Ppm by weight	834.7×10^{-6}
	Pounds/cu ft	62.43×10^{-12}
Micrograms/liter	Milligrams/cu m	1.0
	Micrograms/cu m	1000.0
	Ppm by volume (20°C)	$\frac{24.04}{M}$
	Ppm by weight	0.8347
	Pounds/cu ft	62.43×10^{-9}
ppm by volume (20°C)	Milligrams/cu m	$\frac{M}{24.04}$
	Micrograms/cu m	$\frac{M}{0.02404}$
	Micrograms/liter	$\frac{M}{24.04}$
	Ppm by weight	$\frac{M}{28.8}$
	Pounds/cu ft	$\frac{M}{385.1 \times 10^{6}}$
ppm by weight	Milligrams/cu m	1.198
	Micrograms/cu m	1.198×10^{3}
	Micrograms/liter	1.198
	Ppm by volume (20°C)	$\frac{28.8}{M}$
	Pounds/cu ft	7.48×10^{-6}

Table E-1
Atmospheric Gases

TO CONVERT FROM	TO	MULTIPLY BY
Pounds/cu ft	Milligrams/cu m	16.018×10^{6}
	Micrograms/cu m	16.018×10^{9}
	Micrograms/liter	16.018×10^{6}
	Ppm by volume (20°C)	$\frac{385.1 \times 10^{6}}{M}$
	Ppm by weight	133.7×10^{3}

Table E-2
Atmospheric Pressure

TO CONVERT FROM	TO	MULTIPLY BY
Atmospheres	Millimeters of mercury	760.0
	Inches of mercury	29.92
	Millibars	1013.2
Millimeters of mercury	Atmospheres	1.316×10^{-3}
	Inches of mercury	39.37×10^{-3}
	Millibars	1.333
Inches of mercury	Atmospheres	0.03333
	Millimeters of mercury	25.4005
	Millibars	33.35
Millibars	Atmospheres	0.000987
	Millimeters of mercury	0.75
	Inches of mercury	0.30
Sampling Pressures		
Millimeters of mercury (0°C)	Inches of water (60°C)	0.5358
Inches of mercury (0°C)	Inches of water (60°C)	13.609
Inches of water (0°C)	Millimeters of mercury (0°C)	1.8663
	Inches of mercury (0°C)	73.48×10^{-2}

Table E-3.
Velocity

TO CONVERT FROM	TO	MULTIPLY BY
Meters/sec	Kilometers/hr	3.6
	Feet/sec	3.281
	Miles/hr	2.237
Kilometers/hr	Meters/sec	0.2778
	Feet/sec	0.9113
	Miles/hr	0.6241
Feet/sec	Meters/sec	0.3048
	Kilometers/hr	1.0973
	Miles/hr	0.6818
Miles/hr	Meters/sec	0.4470
	Kilometers/hr	1.6093
	Feet/sec	1.4667

Table E-4.
Atmospheric Particulate Matter

TO CONVERT FROM	TO	MULTIPLY BY
Milligrams/cu m	Grams/cu ft	283.2×10^{-6}
	Grams/cu m	0.001
	Micrograms/cu m	1000.0
	Micrograms/cu ft	28.32
	Pounds/1000 cu ft	62.43×10^{-6}
Grams/cu ft	Milligrams/cu m	35.3145×10^{3}
	Grams/cu m	35.314
	Micrograms/cu m	35.314×10^{6}
	Micrograms/cu ft	1.0×10^{6}
	Pounds/1000 cu ft	2.2046

Table E-5
Concentration

TO CONVERT FROM	TO	MULTIPLY BY
Grams/cu m	Milligrams/cu m	1000.0
	Grams/cu ft	0.02832
	Micrograms/cu m	1.0×10^{6}
	Micrograms/cu ft	28.317×10^{3}
	Pounds/1000 cu ft	0.06243
Micrograms/cu m	Milligrams/cu m	0.001
	Grams/cu ft	28.43×10^{-9}
	Grams/cu m	1.0×10^{-6}
	Micrograms/cu ft	0.02832
	Pounds/1000 cu ft	62.43×10^{-9}
Micrograms/cu ft	Milligrams/cu m	35.314×10^{-3}
	Grams/cu ft	1.0×10^{-6}
	Grams/cu m	35.314×10^{-6}
	Micrograms	35.314
	Pounds/1000 cu ft	2.2046×10^{-6}
Pounds/1000 cu ft	Milligrams/cu m	16.018×10^{3}
	Grams/cu ft	0.35314
	Micrograms/cu m	16.018×10^{6}
	Grams/cu m	16.018
	Micrograms/cu ft	353.14×10^{2}